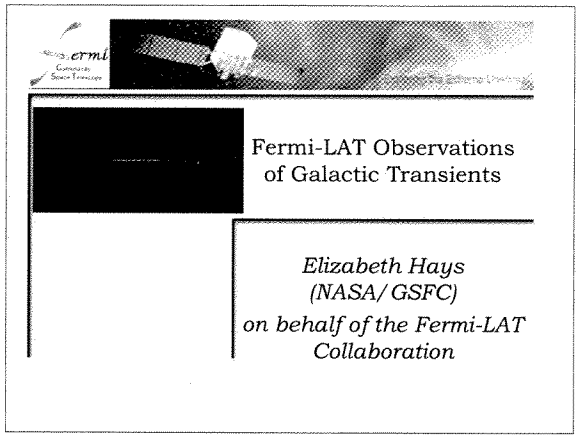
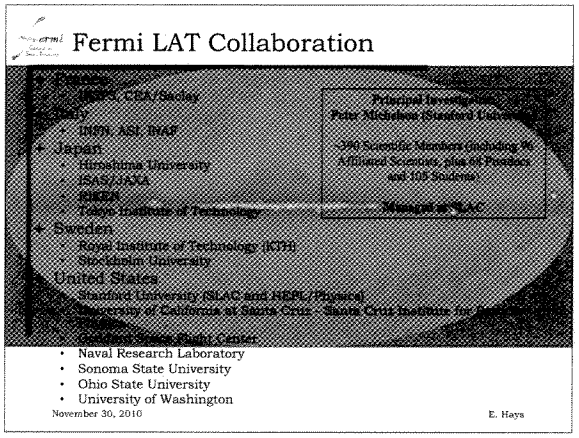
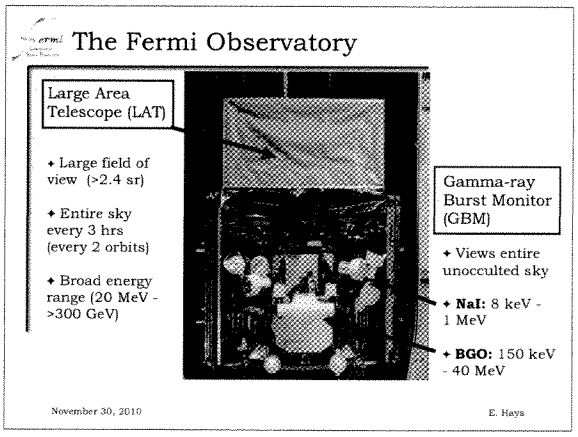
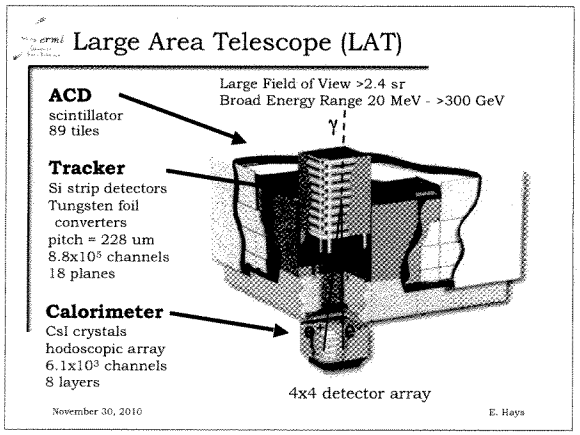

Fermi-LAT Observations
of Galactic Transients
Elizabeth Hays
(NASA/GSFC)
on behalf of the Fermi-LAT
Collaboration


Fermi LAT Collaboration
France
IN2P3, CEA/Saclay
Italy
INFN, ASI, INAF
Japan
Hiroshima University
ISAS/JAXA
RIKEN
Tokyo Institute of Technology
Sweden
Royal Institute of Technology (KTH)
Stockholm University
United States
Stanford University (SLAC and HEPL/Physics)
University of California at Santa Cruz - Santa Cruz Institute for Particle Physics
Naval Research Laboratory
Sonoma State University
Ohio State University
University of Washington
Principal Investigator
Peter Michelson (Stanford University)
~390 Scientific Members (including ~80 Affiliated Scientists, plus 60 Postdocs and 105 Students)
Managed at SLAC
November 30, 2010
E. Hays


The Fermi Observatory
Large Area Telescope (LAT)
✦ Large field of view (>2.4 sr)
✦ Entire sky every 3 hrs (every 2 orbits)
✦ Broad energy range (20 MeV - >300 GeV)
Gamma-ray Burst Monitor (GBM)
✦ Views entire unocculted sky
✦ NaI: 8 keV - 1 MeV
✦ BGO: 150 keV - 40 MeV
November 30, 2010
E. Hays


Large Area Telescope (LAT)
ACD
scintillator
89 tiles
Large Field of View >2.4 sr
Broad Energy Range 20 MeV - >300 GeV
γ
Tracker
Si strip detectors
Tungsten foil converters
pitch = 228 um
8.8x10⁵ channels
18 planes
Calorimeter
CsI crystals
hodoscopic array
6.1x10³ channels
8 layers
4x4 detector array
November 30, 2010
E. Hays

## LAT Sensitivity with Time

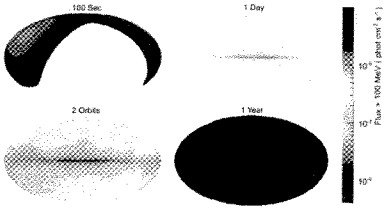
**Transient Science:** Flares, bursts, multiwavelength campaigns, unidentified transients

**Accumulated Science:** New source types, populations, long-term monitoring, spatially extended and diffuse studies

Deepest and most uniform survey of the sky at these energies

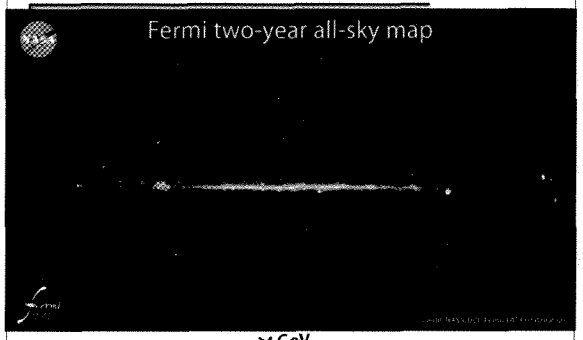
All-sky in ~3 hrs (2 orbits)

Minor asymmetry due to passages through South Atlantic Anomaly





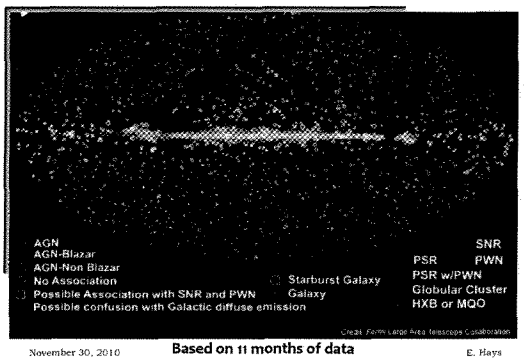

## The Steady Sky




>1 GeV



## 1FGL Catalog

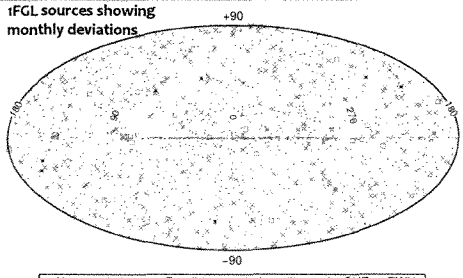



**Based on 11 months of data**



## The Variable Sky

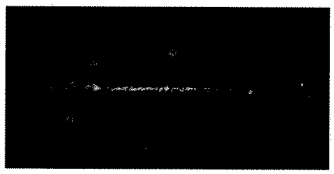
**1FGL sources showing monthly deviations**




| | | | |
|---|---|---|---|
| No association | Possible association with nearby SNR or PWN | | |
| AGN – blazar | Starburst Gal | Pulsar | Pulsar w/PWN |
| AGN – unknown | Galaxy | PWN | Globular cluster |
| AGN – non blazar | | SNR | XRB or MQO |

## LAT Automated Science Processing

All-sky search runs every 6 hours, 1 day, 1 week



LAT counts map
E>100 MeV, 6 hours

LAT flare advocates monitor data daily and trigger multiwavelength follow-up. Also check for interesting transients reported in other wavebands.

- >100 Astronomer's Telegrams
- Public lightcurves through FSSC at **http://fermi.gsfc.nasa.gov/ssc**
- Weekly and Special Reports **http://fermisky.blogspot.com**

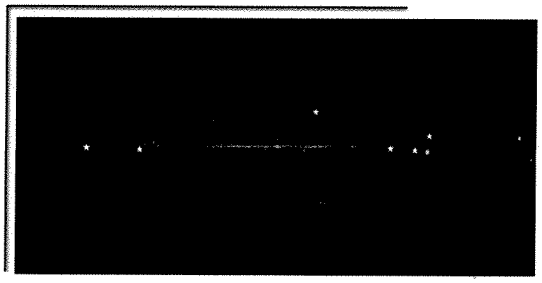


## Flaring Galactic Sources in the LAT

- Search for new transients near the Galactic plane
- Cygnus X-3
- Nova of V407 Cygni
- Crab Nebula



## LAT Unassociated Transient Detections

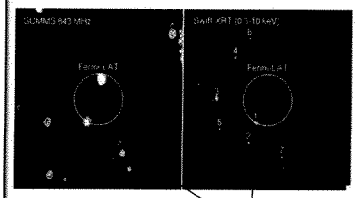


☆ Unassociated transients from daily search

○ Low latitude blazars from First LAT Catalog



## Counterpart Search - Fermi J0910-5041



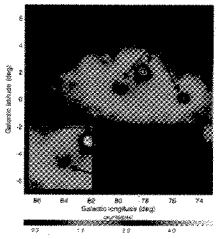

**Fermi J0910-5041**
(ATEL #1788)

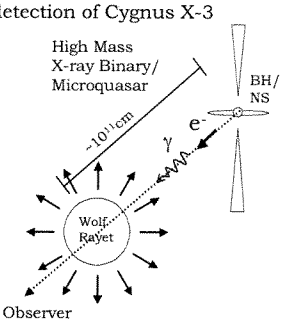
- October 15, 2008
- ~10x above average gamma-ray flux for 2 days
- Swift XRT ToO within 1 day
- 1 of 2 high confidence LAT transients without a firm counterpart

LAT 95% error circle contains Swift XRT source (Landi et al. ATEL #1822) coincident with flat-spectrum radio source from SUMMS and AT20G (Sadler ATEL #1843)

## Cygnus X-3

First secure gamma-ray detection of Cygnus X-3
- high significance source and binary modulation





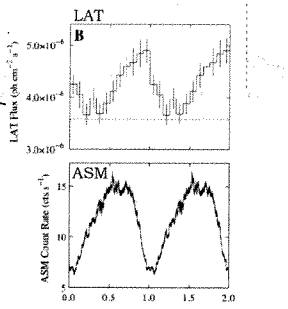

Science 326, 1512 (2009)



## Gamma-ray Flares and Modulation

Aug. 4 2008 to Sept. 2 2009

4 day

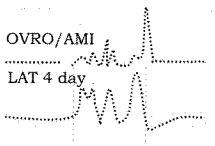



+ LAT active periods correspond to soft X-ray state
+ Gamma rays modulated at 4.8 hour binary period
+ LAT detected a third flare from 2010 May 19-26 during transition to the soft state (Corbel et al. ATEL #2646)



## Connection to Jet Activity

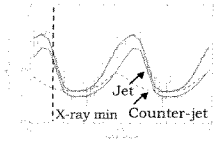
+ LAT active periods correspond to radio flares
  + Possible radio lag is not well constrained by correlation analysis
+ Expect high energy electrons somewhere along the jet to scatter the stellar radiation field (UV) via inverse Compton
  + Superior conjunction favored for gamma-ray production

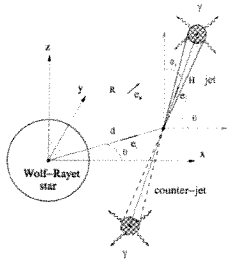





## Probing the Jet

+ Gamma ray origin away from accretion disk to avoid absorption on soft X-rays
+ Modulation provides test of jet inclination
+ Also sensitive to jet precession



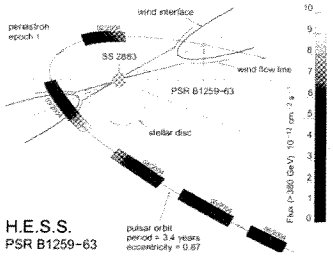




Model fits require inclined jet and prefer site slightly outside orbital separation

Dubus, Cerutti, and Henri, MNRAS, 404, L55 (2010)

## A Binary Transient in the LAT Future?

- First periastron passage of PSR B1259-63 since Fermi launch
  - Superior conjunction Dec. 7
  - Closest approach on Dec. 14
- Multiwavelength campaign Nov. - Feb.
- LAT contact: aous.abdo at nrl.navy.mil
- Actively monitored by team - stay tuned!

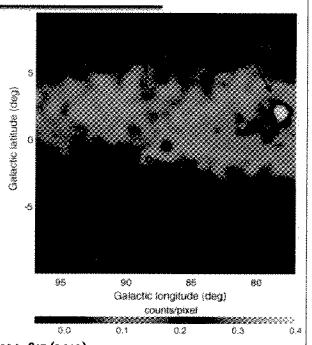



No significant emission in LAT data yet
Abdo et al. ATEL #3054



## Gamma Rays Concurrent with a Nova

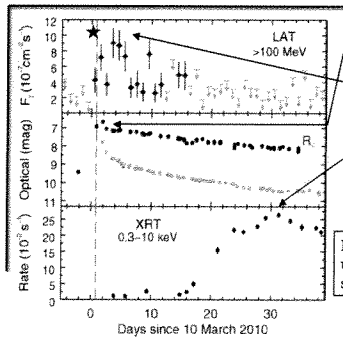
- Fermi J2102+4542: First detection of a nova in gamma rays
- 6-8σ in automated processing on 2010 March 13, 14 (Cheung et al. ATEL #2487)
- LAT position within 3.7' of V407 Cygni (white dwarf, red giant binary)
- Further analysis shows gamma rays close in time to nova discovery on March 10 by Nishiyama and Kabashima




Science 329, 817 (2010)



## Nova Lightcurves




1) Optical peaks first

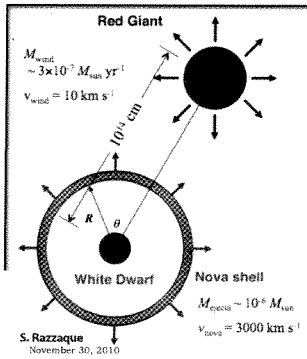
2) Gamma rays peak at 3-4 days and last ~2 weeks

3) X-rays peak at ~30 days, last and longest

Relative timing can be understood from the system geometry



## V407 Cygni System



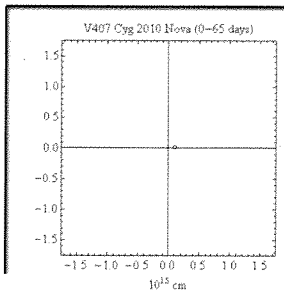

Uncommon symbiotic binary - accretion fed by stellar wind

Nova shell provides means to accelerate electrons and ions.

RG atmosphere and wind provide asymmetric distribution of radiation and material for gamma-ray production processes.

S. Razzaque
November 30, 2010

## Gamma-ray and X-ray Evolution




S. Razzaque

Sedov condition is reached in a few days toward the red giant

Gamma rays peak early when efficiency for pion and inverse-Compton processes is favorable

X-rays peak later, increasing with volume of shock-heated gas

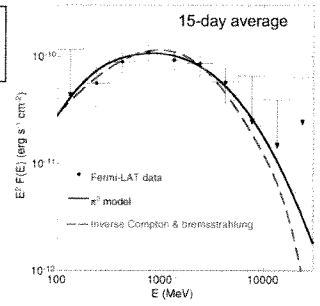
Shell expansion is nonuniform in space



## Emission Mechanisms

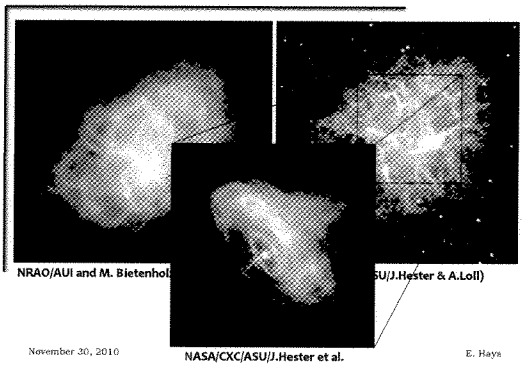
Spectral curvature does not evolve significantly

- Energetics
  - Kinetic energy of the shell: ~$10^{44}$ erg
  - Total energy in γ-rays: ~$4x10^{41}$ erg
  - This means 0.4% efficiency for leptonic scenarios
  - Or 9% for hadronic (similar to Fermi SNR)



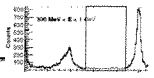



## The Crab Nebula



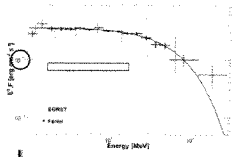


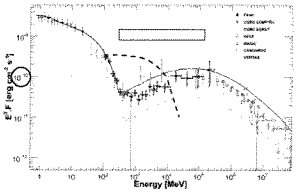

## The Crab in LAT



**Pulsar** 100 MeV to 20 GeV

**Nebula** from MeV to TeV




Hyper-exponential cutoff excluded at ~5 sigma

Consistent with emission well above the neutron star surface

Two components: Synchrotron + Inverse Compton extending to TeV. Fit consistent with mean nebula B field of 100 to 200 μG

## Our candle is not so standard

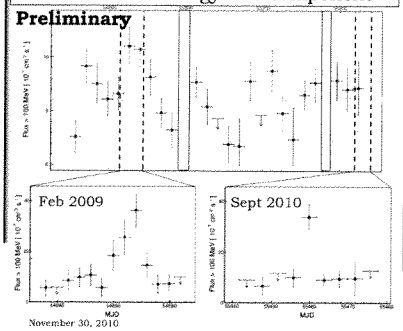
- Crab flickers in hard X-ray
  - Fermi GBM reports hard X-ray variability on ~yearly time scales. Confirmed by multiple instruments (C. A. Wilson-Hodge et al. arXiv:1010.2679v1)
- Crab flares at high energy (>100 MeV)
  - AGILE reports enhanced Crab flux over a few days, Sept. 19-21 (M. Tavani et al. ATEL #2855)
  - Fermi LAT confirms flare and triggers LAT ToO (R. Buehler et al. ATEL #2681)
    - Earlier flare found using new offline all-sky variability search developed by R. Buehler
  - Fermi LAT reports end of flare. Variability present in off-pulse phase of pulsar (E. Hays et al. ATEL #2893)



## Two Short Flares from the Nebula

Flux of the low energy LAT component

**Preliminary**




No variability found in pulsar or high energy LAT component

4 week intervals *Sun passages excluded*

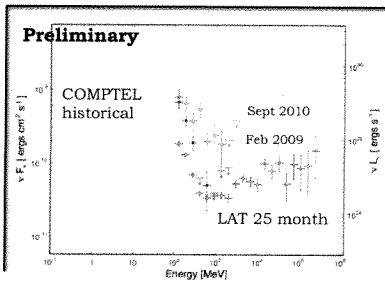
4 day intervals covering flare periods

**arXiv:1011.3855v2**



## Crab Flare Spectra

**Preliminary**




Low energy LAT component shows spectral variability

25 month index: 3.69 ± 0.11

Feb 2009 index: 4.3 ± 0.3

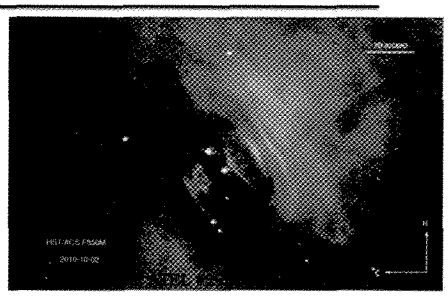
Sept 2010 index: 2.7 ± 0.2



## Origin of the Gamma-ray Flares?

- Gamma-ray luminosity is a small fraction of the pulsar power ($10^{35}$ erg/s -> ~$10^{-3}$ $L_{rot}$)
- 4 day duration implies small region size, diameter < 1.4 x $10^2$ pc (1.5 arcsec)
- Electron synchrotron cooling time in 200 uG < ~15 days
- LAT low energy spectral form + short timescale variability support a synchrotron interpretation
  - Implies electrons accelerated to >PeV in structures in the inner region near the termination shock and base of the jet

## Searching for the Emission Region



No corresponding variability found in radio, optical, infrared, soft and hard X-rays at time or shortly after the 2nd LAT flare



## Summary

- LAT all-sky monitoring is producing spectacular results for the GeV transient sky
  - New blazars and unidentified transients
  - Probing the jet of the Cygnus X-3 microquasar
  - Discovery of gamma rays from V407 Cygni nova
  - Fast high-energy gamma-ray flares from the Crab
  - All-sky monitoring continues. What's next?

**http://fermi.gsfc.nasa.gov**



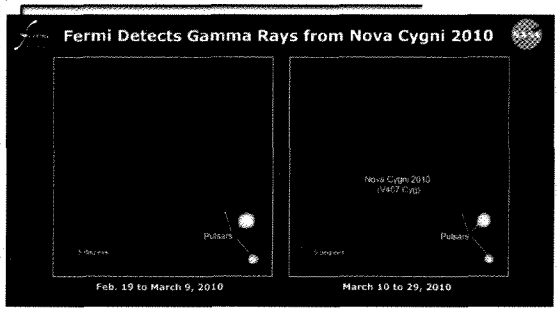
Extras



## Other Binary Outbursts in LAT?

- No LAT detections of Cygnus X-1
  - Flux (0.1-3 GeV) < 4x10-7 ph $cm^{-2}$ $s^{-1}$ during flare reported by AGILE 2009 Oct 16
  - Nothing found for 2010 March 23-24 period reported by AGILE of during MAXI/GSC soft X-ray brightening June 2010
- Nothing found yet for black hole candidates GX 339-4, GRS 1915+105
- Eta Carinae consistent with steady emission (includes 2008 periastron)

## LAT Before and After




LAT >100 MeV counts maps



## Historical Optical Lightcurve